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Comparison of the relative risk of molar
root perforations using various endodontic
instrumentation techniques

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ABSTRACT

One hundred canals in the mesial roots of sixty mandibular
molars were instrumented using five techniques. The remaining
twenty canals became uninstrumented controls. A standard
technique without flaring and four techniques with flaring were
evaluated. Two of the flare techniques used only hand instrumenta-
tion (circumferential and anticurvature) while two used additional
engine-driven instrumentation (round burs and Gates-Glidden burs).
Of the flare techniques, hand instrumentation used in an anti-
curvature manner showed significantly less risk ($p < .005$) to the
bifurcation root surface. The engine-driven techniques were not
significantly different than circumferential hand instrumentation
in their risk to the bifurcation area.

An analogy may be drawn between operative dentistry and endodontics. The ideal in operative dentistry would be to remove the diseased tooth structure (caries) and permanently seal the cavity with an inert filling material. The ideal in endodontics would be to remove the diseased pulp tissue and permanently seal the root canal system with an inert filling material. If the analogy is carried even further, flaring of the root canal preparation may be compared to the convenience form of the cavity preparation (1). The convenience form allows instruments to have easier access to the cavity for excavation and restoration. Flaring accomplishes a similar function. It allows endodontic instruments to reach the critical area of the apical third of the root canal for proper preparation and obturation (2,3,4).

The completed root canal preparation should be a continuous tapering funnel with the cross-sectional diameter decreasing as the apex is approached (2). In 1976, Weine *et al.* (5) studied the effect that the instrumentation technique had on the original shape and the apical foramen location in curved canals. They found that none of the instrumentation techniques studied produced a completely funnel-shaped preparation from orifice to apex. The narrowest portion of the preparation was near the middle of the curve instead of the apex. They stated that the preparation had an hourglass appearance and called the narrowest area the "elbow". They suggested the use of a flared preparation in the coronal aspect in order to eliminate the "elbow". With this addition to the instrumentation technique, a continuously tapering funnel might be produced.

Other reasons are cited for flaring the coronal portion of the root canal preparation (2-6). First, flaring allows removal of all interferences in the coronal and middle thirds of the canal. This insures that all instrumentation in the apical third of the canal will be under the control of the operator (2). Second, a greater coronal diameter allows the needle of the irrigating syringe to penetrate further apically. This allows the irrigant to function closer to the apex (6). Senia, Marshall and Rosen's (7) study indicated that the efficiency of the irrigating solution is likely limited by the diameter of the canal. Third, a flared coronal area allows the pluggers and spreaders to properly condense the apical gutta percha (3-5). Allison, Weber and Walton (4) have shown that to totally obturate a canal, the gutta percha must be condensed throughout the prepared space.

It has been shown that all mesial roots of mandibular first molars have a concavity on the distal surface. The mean root concavity has been measured as 0.7 ± 0.19 mm (8). In most instances, the concavity of the mesial root was greater than that of the distal root (8). The mesiobuccal and mesiolingual canals are thus closer to the distal surface than they appear on the radiograph. There is a danger of perforation if the distal wall of these canals are flared to too large a size (1,3,9). Perforations in the bifurcation area of mandibular molars are more common than is acceptable and lead to failures (10,11).

Many methods of flaring the coronal third of the root canal preparation have been suggested (2,5,6,12,13). Basically, the

techniques can be divided into two groups: those techniques employing hand filing and reaming, and those techniques employing engine-driven burs. Files used in two different ways (circumferential and anticurvature) have been recommended for flaring the preparation. In contrast to circumferential filing, which tries to use equal filing against all canal walls, anticurvature filing is primarily done toward the areas of greatest bulk of the root (12). For example, in the mesio-buccal canal of a mandibular molar, the mesiobuccal walls of the canals would receive the greatest amount of instrumentation. It has been claimed that this method of filing will reduce the risk of perforation (12).

The use of Gates-Glidden burs (Union Broach Co., Long Island City, NY) in an up-and-down motion has also been recommended for flaring the preparation (6,9,13). Some authors recommend inserting the Gates-Glidden bur deep into the canals to a depth of 15-17 mm or the coronal two-thirds of the root (6,9,14). Other authors indicate entering the canal to a lesser degree, "several" mm beyond the orifice or one and one-half the length of the drill head (4,15). Weine (3) has stated that in thin or curved roots, if the Gates-Glidden drill is used to a depth greater than the cervical third or fourth, danger of lateral perforations increases. He has also recommended that they only be allowed to cut during withdrawal. This danger of perforation has led Schilder (2) to recommend that burs not be used in cleaning and shaping procedures.

Due to their design, Gates-Glidden burs tend to enlarge the
canal uniformly. As with circumferential filing, this cutting
characteristic should theoretically increase the chances of a
lateral perforation occurring in the mesial roots of mandibular
molar teeth. If Gates-Glidden drills are used with a lateral
force to counteract this, they break easily. Even when used with
an in-and-out motion with little lateral force, Abou-Rass and
Jastrab (13) stated that they break frequently. Due to their thicker
shank, round burs resist breakage when used with a lateral force.
Thus, the operator has greater control, and can flare the
preparation toward the area of the greatest bulk of the root or
in an anticurvature manner. However, several authors have warned
against placing round burs down the canals due to the possibility
of perforation (3,16).

The purpose of this study was to determine the relative
risk of accidental perforation of the mesial canal of mandibular
molars posed by four methods of coronal flaring: Hedstroem
instruments using the circumferential filing technique; Hedstroem
instruments using the anticurvature filing technique; Gates-Glidden
drills using a push-pull technique; and round burs using anticurva-
ture pressure.

MATERIALS AND METHODS

A representative sample of sixty extracted human mandibular
first and second molars, stored in 10% formalin, was selected for
the study. Any teeth that had unusual root morphology, damage from
extraction, or gross caries, were excluded from the sample. The

teeth were placed in a 5.25% sodium hypochlorite solution for 30

minutes in order to remove soft tissue on the root surface. The

teeth were gently cleaned with an ultrasonic scaler to remove

any remaining soft tissue or calculus. To insure orientation

after sectioning, a shallow groove was made on the lingual

surface of each mesial root with a No. 1/2 round bur (Fig 1C).

The occlusal surface of each tooth was ground flat and a standard

access opening made as described by Cohen and Burns (16). The

teeth were randomly placed into three groups of twenty (17). Two

techniques were used to prepare the teeth in each group. In each

of the groups, ten of the mesiobuccal canals and ten of the mesio-

lingual canals were randomly instrumented using one technique. The

remaining canal in each root was then instrumented using the other

technique. This was done to randomize the variables due to tooth

morphology. This resulted in two subgroups of twenty canals in

each group of twenty teeth. Each subgroup received a different

treatment. A new set of instruments was used in each canal for

all procedures. During instrumentation, all canals were irrigated

with a 5.25% sodium hypochlorite using a standard endodontic

irrigating syringe (Monoject Endodontic Syringe, Sherwood Medical

Co., St. Louis, MO), and the canals left flooded during instru-

mentation. A total of 20 ml of irrigant was used in each instru-

mented canal.

GROUP 1 (Controls)

The first twenty canals in Group 1 were left uninstrumented

(Group 1A). The remaining twenty canals (Group 1B) were instrumented

in a standard manner without additional flaring of the coronal portion
of the canal. A working length was determined using a No. 10 file.
The working length was 1 mm short of where the file was first seen.
The canals were instrumented circumferentially to the working length,
up to a size No. 35 file.

GROUP 2 (Hand-Instrument Flaring)

All canals were instrumented using serial preparation. A working
length was determined as described and the apical portion of the
canal instrumented to a size No. 35 file. Then the body of the canal
was instrumented serially. Each larger instrument was used 1/2 mm
short of its predecessor until a No. 60 file was reached. Last,
the coronal portion of the preparation was flared with a No. 60
Hedstroem file to the depth reached by the last instrument used.
Each canal in Group 2A was filed by each instrument in a circum-
ferential manner. That is, each instrument was used against all
walls in as equal a manner as possible. The twenty canals in Group
2B received anticurvature filing as described by Abou-Rass *et al.* (12).
That is, the major portion of the flaring and filing was toward what
they called the bulky or safety zones. That would be toward the
mesiobuccal for the mesiobuccal canals and mesiolingual for the
mesiolingual canals (Fig 1D).

GROUP 3 (Engine-Driven Flaring)

The apical portion and the body of each mesial canal was serially
prepared as described for Group 2. The coronal portion of the
preparation was flared using engine-driven instruments. The canals in
Group 3A were flared with No. 2 and 3 Gates-Glidden drills. Group 3B

had its twenty canals flared using No. 2 and 4 round burs. The
Gates-Glidden drills were used in the manner described by Coffae
and Brilliant (6), and Mullaney (14). The main difference in
techniques was that the round burs were used with a lateral force
toward the bulky or safety zones or in the same manner as anti-
curvature filing (Fig 1D).

All the teeth from the three groups were treated as follows.
The lingual two-thirds of each tooth was embedded in clear ortho-
dontic resin (The L.E. Caulk Company, Milford, Delaware), using
50% excess monomer. The resin was allowed to harden for 24 hours
(Fig 1A). The long axis of the mesial root was determined by the
method described by Schneider (18). Four cuts were made perpendi-
cular to the long axis of the root, using a new diamond disk in a
thin sectioning machine (Bonwill TSM 77, San Francisco, CA) which
made cuts about 0.8 mm thick. The first cut was made so its top
edge was 2.0 mm occlusal of the bifurcation. The top of the
second cut was at the bifurcation and the top of the third and
forth cuts were 2 and 4 mm apical to the most occlusal point of
the bifurcation (Fig 1B,2). This resulted in 3 sections, about
1.2 mm wide (Fig 1C). In order to evaluate how close the various
techniques came to perforating the root surfaces, a measuring
microscope (Nikon Measurescope, Nikon, Inc., Garden City NY) was
used. Measurements were made on the occlusal and apical surface
of each of the two sections apical to the bifurcation (Fig 2).
This resulted in 4 measurement levels, 0.8, 2.0, 2.8, and 4.0 mm

apically from the highest point in the bifurcation. For each
canal, three measurements were taken, the shortest distance from
the canals to the distal and mesial surfaces of the mesial root
and the diameter between these two areas (Fig 1D). Photographs
were taken of representative sections.

RESULTS

Table 1 gives the average thickness of dentin and cementum
remaining in the mesial root from the canal to the distal or
bifurcation area for each technique at each level. Figure 3 shows
the same data graphically. Most of the basic individual variations
are easily seen, although an analysis of variance of all data in
respect to both levels and techniques did show interactions.
Therefore, further statistical analysis of overall interrelationship
of levels and techniques was not indicated. However, range tests of
individual levels did show various degrees of significance between
techniques. The standard technique removed significantly less dentin
than the other techniques. For the first three levels, the signifi-
cance of the difference was always at a $p<.05$ which is generally
considered statistically significant. Of the four flare techniques
(2A, B and 3A, B), at all levels, the anticurvature technique left
the greatest average thickness of dentin. The greatest difference at
level one was between the circumferential (2A) and anticurvature (2B)
techniques, with a T-value of 2.113 and a significance of $p<.05$. The
Gates-Glidden technique left the least average thickness at all but
the first level. The significance between the anticurvature (2B) and
Gates Glidden (3A) for these levels were: level 2, $T=2.099$, $p<.05$;

level 3, T=3.001, p<.01; and level 4, T=1.900, p<.08. At level two,

the difference between the hand techniques was p<.10. The p>.05 is

generally not considered statistically significant. The differences

between circumferential instrumentation and the mechanical instru-

mentations were also all at a level generally considered non-

significant (p>.05).

   Table 2 shows the numbers of sections for each technique for

which there was less than 0.5 mm of dentin left between the canal

and the bifurcation. Since there were only a few sections less

than .4 mm thick, statistical analysis was of real value only for

the total number of sections less than .5 mm thick. Fisher's

exact probability tests showed a difference at a significance level

of p<.05 between the unprepared group and the standard preparation

group. Chi-square analysis of these totals showed a difference

between all instrumentation techniques of a p<.005. The sum

of squares was partitioned to show where specific differences were

between individual techniques. This data is presented below the

table. The lines connect the techniques not different at a

significance of p<.05. That means the circumferential technique (2A)

was significantly different from the Gates-Glidden (3A), but not

from the round bur (3B). However, the differences were not at a

p<.05 level of significance between the Gates Glidden (3A) and

round bur (3B) groups. Using Chi-square with Yates' correction

factor, there was a significant difference between the anticurvature

group and each of the other flare techniques at a p<.005 level.

Figure 4 shows the data graphically.

Table 3 shows the total number of sections of each technique at each level where the dentin was less than .5 mm thick. Chi-square analysis of the data showed a difference between levels of a $p < .005$. Again, the relationship between individual levels is shown below the table. Lines connect levels not different at a significance of $p < .05$. Therefore, level 1 had significantly less of the thin sections than levels 2-4. Also, level 3 had significantly more thin sections than any other level. Figure 5 shows the data for levels graphically.

Table 4 and Figure 6 give the data for the thicknesses of cementum and dentin remaining from the canal to the mesial tooth surface of the mesial root. Again, the standard technique consistently removed less dentin than the flare techniques. Of the flare techniques, at the first level, the round bur was significantly different from each of the others at a $p < .001$ level. Even though the round bur did thin the mesial wall to the greatest degree, the thickness of the wall was usually greater than that seen with any of the flare techniques on the distal. There were no perforations on the mesial. In only one case did a wall get as thin as .2 mm. In 6 of the 80 sections, the walls were thinner than .5 mm.

Figure 7 shows the mean diameters in a mesio-distal direction after each instrumentation technique. The mechanical techniques did enlarge the canals to the greatest degree.

DISCUSSION

Prior to discussing the actual findings, some mention of the actual exactness of level position can be made. An attempt was made

to make every cut exactly the same thickness. As can be seen in Figure 1B, during individual cuts, the saw blade could deviate slightly. When measured, none deviated more than .2 mm. The width of the cuts made by the saw blade was quite consistent and, of those measured, averaged .82 mm wide.

The greatest area of concern during instrumentation of mesial roots of mandibular molars did prove to be the distal wall. This study did confirm, that of the flare techniques, anticurvature filing using hand instruments left significantly thicker dentin on these walls. Circumferential flaring with hand instruments left very close to the same averages of dentin on the distal as the round bur used in an anticurvature manner. Therefore, this study confirmed that use of instruments in the canal in an anti-curvature manner helps protect the distal wall from perforation. However, hand instrumentation in an anticurvature manner offered greatest protection. As indicated the significance varied, but for incidence of less than .5 mm of dentin remaining at level 1, its difference from other flare techniques was at a p .005 level. In fact, anticurvature hand instrumentation was not significantly different in endangering the bifurcation from standard instru-mentation without special flaring.

Some mention of the determining factors for standard prepara-tion can be made. Walton (15) described standard preparation as instrumenting to a point at least two sizes larger than where the file is first covered by clean dentin shavings. In these small molar canals, instrumenting to a size #35 file always enlarged them at least to this point. Therefore, this size was used in order to

make as consistent a stepping-off point for the continuing procedures
as possible.

Some question may arise on the thicknesses of the canal walls
prepared by the anticurvature techniques in respect to the canal
walls prepared by a circumferential technique. Those prepared by
an anticurvature technique were not only much thicker toward the
bifurcation (Fig 3), but were also slightly thicker on the mesial
(Fig 6). Part of the reason could relate to the fact that the
diameter mesio-distally of the canal after instrumentation was
slightly less (Fig 7). However, this would not account for the
degree of difference. The actual reason is probably shown by
considering the kidney bean configuration of the root in Figure 1D.
The thinnest portion of the root is usually mesio-lingual and disto-
lingual in respect to buccal canals and mesio-buccal and disto-buccal
in respect to lingual canals. While circumferential filing will
tend to move the canal equally toward all walls, the anticurvature
filing is actually away from these thin areas. Therefore, it will
tend to transpose the canal into the bulkier areas of the root or
away from the areas of concavity (mesiobuccally in respect to
buccal canals and mesio-lingual in respect to lingual canals). This
resulted in a teardrop-shaped canal system with actual area of
canal space present after anticurvature filing being greater than
the figures (2, 5, and 6) indicate. This resulted in the measurement
variation, since the diameter measurement was made from the thinnest
area of the distal wall to the thinnest area of the mesial wall,

not across the area of greatest width (Fig 1D). The significant point was that of the flare techniques, the anticurvature filing with files did leave thicker walls in both areas where the canal walls are normally thinnest (Fig 1C,D).

The main area of concern for this study is whether it is safe to use burs to complete flaring of the canal prior to obturation. In this study, the canal was perforated in only one case (two levels of one round bur canal). In fact, this one case listed as a perforation was questionable since it appeared to be in an area of external root resorption. The perforation would likely have occurred irrespective of technique used. The study did indicate that, with use of a careful anticurvature technique at the end of instrumentation, flaring could be accomplished, using burs, with some safety. However, it must be realized these teeth were instrumented under optimal conditions, *in-intro* not *in-vivo*.

It was interesting that on the distal, where the thinnest walls were left, the round bur used in an anticurvature manner always left a slightly greater average thickness of dentin than the Gates-Glidden burs did. Except for the one perforation area, the number of very thin walls was always less with use of the round bur (Table 2 and Figure 4). This happened in spite of the fact that the #2 round bur has a slightly greater diameter than even a #3 Gates-Glidden bur. Using the measuring microscope, the average diameter of five #2 round burs was .952 mm and of five #3 Gates-Glidden was .913 mm.

It could be questioned if the round bur always penetrated as deeply as the Gates-Glidden. Clinically, the attempt was made to use all burs to approximately the same level. However, when Figure 1D is evaluated, while the round bur has obviously passed the third level, it may not have reached the forth level. Also, the mean diameter of the canal space at the forth level for the round bur drops below 1.0 mm (Fig 7), or about the diameter of the #2 round bur itself. However, as discussed previously, the widest diameter of the canal was not necessarily measured (Fig 1D). This was especially true in cases using an anticurvature technique, which was the case with the round bur.

Use of the round bur in an anticurvature manner did result in thinner mesial walls than those created by the Gates-Glidden burs (Table 4). Yet, in the 80 sections, only 6 of the thinner walls was less than 0.5 mm thick. This is about the same as the standard preparation did on the distal surface of the mesial root. Therefore, if burs are used carefully, the potential of perforation of the mesial wall appears minimal. It must be remembered that due to the loss of tooth structure, there is a potential for these roots to be weaker.

Finally, in respect to the use of burs in the canals, it appears that the #2 and #4 round burs used carefully in an anticurvature manner are as safe or safer than the #2 and #3 Gates-Glidden used in an in-and-out motion. Therefore, if burs are to be used in canals, it would appear that the safest procedure might be use of only the #1 and #2 Gates Glidden burs in an anticurvature manner. This would relate well to Weine's (3) recommendation to only allow them to cut

during withdrawal, but in addition, use an anticurvature or lateral

force during withdrawal. Unfortunately, as stated, it is difficult

to use Gates-Glidden burs with lateral forces without breaking them.

Therefore, the general tendency is to use them clinically in

an in-and-out motion. This still does not eliminate breakage (13).

SUMMARY & CONCLUSIONS

The mesial roots of 60 mandibular molars (120 canals) were used

to evaluate the risk of perforation during endodontic instrumentation.

Twenty canals served as uninstrumented controls and the remaining 100

canals received 5 different instrumentation procedures. Twenty

canals received a standard instrumentation technique while the

remaining 80 canals received techniques using additional flaring.

Forty canals were flared using only hand-instrumentation, 20 in a

circumferential filing manner, and 20 in an anticurvature filing

manner. The remaining 40 canals were flared using engine-driven

burs, 20 using #2 and 3 Gates-Glidden's burs with an in-and-out

motion, and 20 using #2 and 4 round burs in an anticurvature manner.

The primary findings were:

1. In the mesial root of mandibular molars, the danger of

    creating thin or perforated walls was much greater

    toward the bifurcation.

2. In respect to average thicknesses of dentin remaining

    after instrumentation of the four flare techniques, hand-

    instrumentation in an anticurvature manner left signifi-

    cantly thicker dentin toward the bifurcation.

3. Also, in respect to average dentin thicknesses remaining,

    the round bur and Gates-Glidden burs did not make the walls

significantly thinner toward the bifurcation than flaring
with hand instruments in a circumferential manner.

4. In respect to number of sections with less than .5 mm of
   dentin remaining toward the bifurcation of the four flare
   techniques, hand-instrumentation in an anticurvature
   manner had significantly fewer.

5. Also, in respect to sections thinner than .5 mm, the
   Gates-Glidden technique had significantly more than
   circumferential filing with hand-instruments. Those
   instrumented by round burs did not.

6. On the mesial wall, the round bur left significantly less
   dentin than all other techniques. However, except for
   the round bur technique at the first level, the average
   thickness of the mesial walls was always greater than
   the average thicknesses left by each flare techniques
   toward the bifurcation.

7. The data appear to support the premise that, if burs or
   files are used in canals for flaring purposes, they should
   only be used in an anticurvature manner. However, further
   study is needed in respect to the use of the Gates-Glidden
   burs in this manner and their tendency to break.

8. Level 3 had the greatest number of thin sections toward the
   bifurcation. This level was 2.8 mm apical of the bifurcation
   which would usually be 4-6 mm apical to the canal chamber
   orifice. Therefore, special care must be used when flaring
   canals to this level.

In conclusion, in respect to endangering the dentinal walls toward the bifurcation, of the flare techniques, anticurvature hand-instrumentation was safest. Of the engine-driven techniques, the #4 and #2 round burs, used carefully in an anticurvature manner, were as safe or safer than the #3 and #2 Gates-Glidden burs used in an in-and-out motion.

The opinions contained herein are the private views of the authors and are not to be construed as official or as relfecting the views of the Department of the Army or the Department of Defense.

Commercial materials and equipment was identified in this resport to specify the investigation procedures. Such identification does not imply recommendation or endorsement, or that the materials and equipment are necessarily the best available for the purpose.

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REFERENCES

1. Ingle JI, Beveridge EE. Endodontics. 2nd ed. Philadelphia: Lea & Febiger, 1976.

2. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am 1974;2:269-96.

3. Weine FS. Endodontic therapy. 2nd ed. Saint Louis: CV Mosby, 1976.

4. Allison DA, Weber CR, Walton RE. The influence of the method of canal preparation on the quality of apical and coronal obturation. J Endodon 1979;5:298-04.

5. Weine FS, Kelly RF, Lio PJ. The effect of preparation procedures on original canal shape and on apical foramen shape. J Endodon 1975;1:255-62.

6. Coffae, KP, Brilliant JD. The effect of serial preparation versus nonserial preparation on tissue removal in the root canals of extracted mandibular human molars. J Endodon 1975;1:211-14.

7. Senia ES, Marshall FJ, Rosen S. The solvent action of sodium hypochlorite on pulp tissue of extracted teeth. Oral Surg 1971; 31:96-03.

8. Bower RC. Furcation morphology relative to periodontal treatment. J Periodontol 1979;50:366-74.

9. Klayman SM, Brilliant JD. A comparison of the efficacy of serial preparation versus giromatic preparation. J Endodon 1975; 1:334-37.

10. Harris WE. A simplified method of treatment for endodontic perforations. J Endodon 1976; 2:126-34.

11. Meister F. Jr, Lommel TJ, Gerstein H, Avies EE. Endodontic perforation which resulted in alveolar bone loss. Oral Surg 1979; 47:463-70.

12. Abou-Rass M, Frank AL, Glick DH. The anticurvature filing method to prepare the curved root canal. J Am Dent Assoc 1980; 101:792-94.

13. Abou-Rass M, Jastrab RJ. The use of rotary instruments as auxiliary aids to root canal preparation of molars. J Endodon 1982; 8:78-82.

14. Mullaney TP. Instrumentation of finely curved canals. Dent Clin North Am 1979;23:593-16.

15. Walton RD. Histologic evaluation of different methods of enlarging the pulp canal space. J Endodon 1976;2:304-31.

16. Cohen S, Burns RC. Pathways of the pulp. 2nd ed. Saint Louis: CV Mosby Co, 1980.

17. Runyon RP, Haber A. Fundamentals of behavioral statistics. 2nd ed. Reading: Addison-Wesley Publishing Co, 1974.

18. Schneider SW. Comparison of canal preparation in straight and curved root canals. Oral Surg 1971;32:271-75.

Table 1. The mean$^{(*)}$ distance and standard deviations$^{(\pm)}$ in millimeters from the canal wall to the distal root surface of the mesial root for each instrumentation technique at each level

| Techniques | L E V E L S | | | |
	1	2	3	4
1A - Unprepared	1.312*	1.152	1.119	1.078
	±.279	.238	.273	.290
1B - Standard	1.021	.826	.807	.854
	.304	.282	.328	.309
2A - Circumferential	.781	.657	.645	.738
	.258	.250	.187	.191
2B - Anticurvature	.933	.780	.703	.732
	.192	.221	.192	.176
3A - Gates-Glidden	.859	.622	.532	.594
	.278	.254	.224	.273
3B - Round Bur	.871	.658	.615	.706
	.316	.313	.315	.284

Table 2.   Number of the 80 sections of each technique instrumented 0.5 millimeers
and closer to the distal root surface of the mesial root

Techniques	>.5	<.5mm	<.4mm	<.3mm	<.2mm	<.1mm	Perf.	Total .5
1A Unprepared	80	0	0	0	0	0	0	0
1B Standard	73	6	1	0	0	0	0	7
2A Circumferential	64	12	3	1	0	0	0	16
2B Anticurvature	76	4	0	0	0	0	0	4
3A Gates-Glidden	53	17	5	4	1	0	0	27
3B Round Bur	61	8	7	0	2	0	2*	19

*Same canal perforated at two adjacent levels, therefore 1 of 20 canals perforated.

For significance of total incidence of less than .5mm of dentin remaining for the
five techniques: df = 4, x^2 = 28.92, p<.005

For the significance of the differences between individual techniques, the
technique not connected by lines were significantly different at a p<.05.

2B	1B	2A	3B	3A
.0500	.0875	.2000	.3115	.3375

Table 3. Number of the twenty sections of each technique
instrumented within 0.5 millimeters from the distal root
surface of the mesial root at each level

| Techniques | L E V E L S | | | | Total |
	1	2	3	4	
1A Unprepared	0	0	0	0	0
1B Standard	1	2	2	2	7
2A Circumferential	1	7	5	3	16
2B Anticurvature	0	0	3	1	4
3A Gates-Glidden	0	7	11	9	27
3B Round Bur	2	5*	7*	5	19
Total	4	21	28	20	73

*Levels where only perforation occurred.

For significance of total incidence of <.5 mm. of dentin remaining
by levels: df = 3, x^2 = 19.95, p<.005.

For significance of differences between individual levels, the
levels not connected by lines were significantly different at
a p<.05.

1	4	2	3
.0333	.1667	.1750	.2333

Table 4. The mean distance$^{(*)}$ and the standard deviations$^{(\pm)}$ in millimeters from the canal wall to the mesial root surface of the mesial root for each instrumentation technique at each level

| Techniques | L E V E L S | | | |
	1	2	3	4
1A Unprepared	1.587*	1.393	1.342	1.245
	±.228	.228	.206	.222
1B Standard	1.436	1.361	1.298	1.188
	.159	.160	.148	.172
2A Circumferential	1.234	1.259	1.225	1.154
	.183	.215	.206	.224
2B Anticurvature	1.258	1.285	1.242	1.162
	.257	.233	.212	.204
3A Gates-Glidden	1.086	1.087	1.101	1.067
	.132	.180	.139	.155
3B Round Bur	.824	.841	.956	1.063
	.257	.279	.302	.265

Representative samples of various techniques at level 1 to give indication of relative significance of differences.

2B and 3A: $T = 2.6$, $p < .05$. 2B and 3B: $T = 5.3$, $p < .001$.
3A and 3B: $T = -4.1$, $p < .001$.

LEGEND

Figure 1.   A.   Tooth mounted in acrylic ready to be sectioned.

            B.   Tooth sectioned with arrow pointing to long axis

                 of mesial root.

            C.   Three sections removed ready for measurement of

                 top two. Arrows point to areas closest to bifurca-

                 tion on the distal.

            D.   Apical section with black lines across thinnest

                 area on mesial (M) and distal (D). White line shows

                 where diameter measurement taken. Broken line shows

                 actual greatest diameter of lingual (L) canal.

                 Buccal (B) canal instrumented by Gates-Glidden bur

                 does not appear moved toward area of greatest bulk,

                 the mesiobuccal (MB). Lingual canal instrumented

                 by round bur shows anticurvature flare to area of

                 greatest bulk, the mesiolingual (ML).

Figure 2.   Diagram of how cuts* and sections** were made perpendicular

            to long axis of tooth. The top of the first cut 2mm. occlusal

            to bifurcation, top of second cut at bifurcation and top

            of third and forth cuts 2 and 4 mm. apical to bifurcation
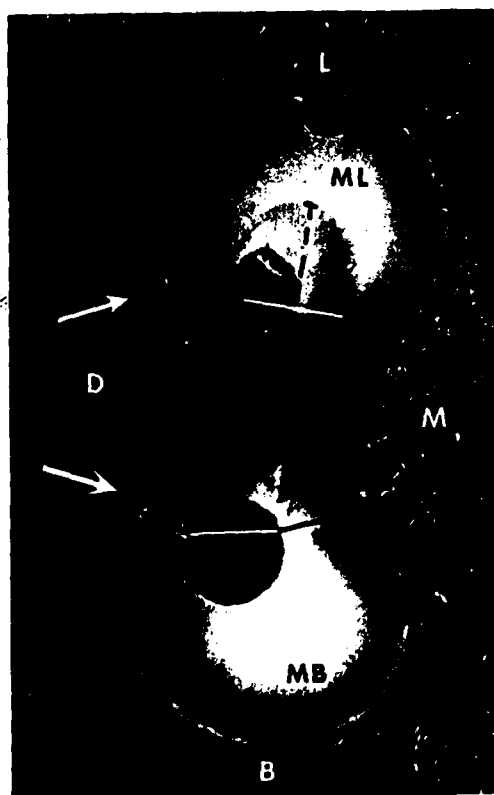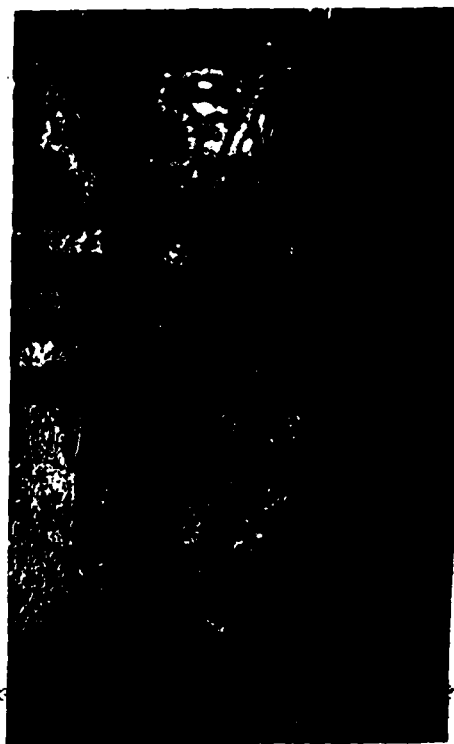
Figure 3.   Mean measurements for each technique of thicknesses of

            distal walls of mesial roots
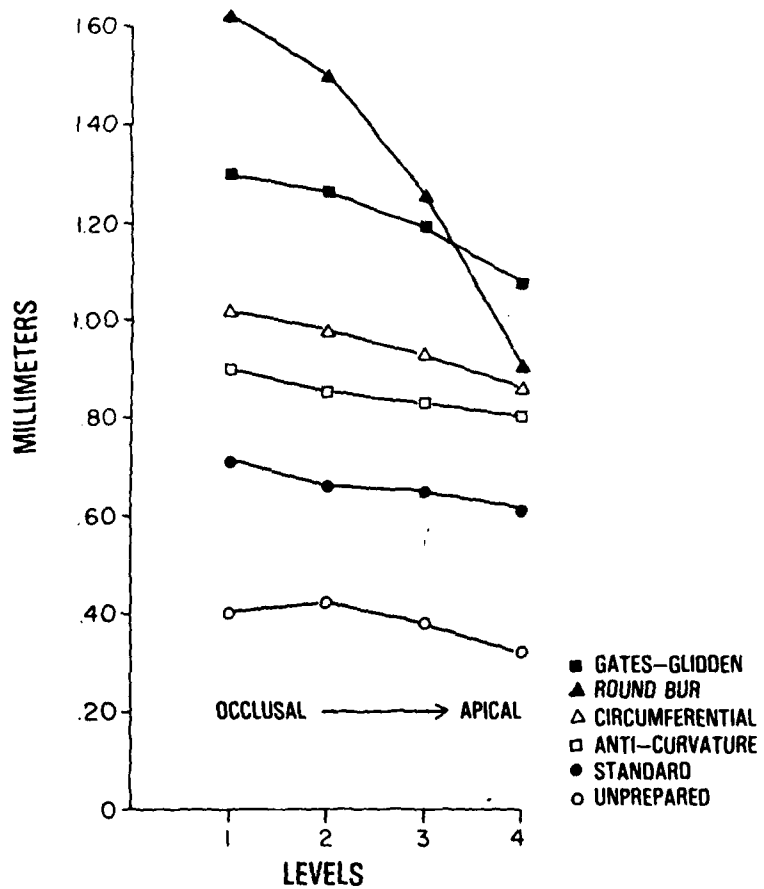
Figure 4.   Diagram of actual number of specimens with less than and

            more than .5mm of dentin remaining in respect to the total

            number of specimens for each technique.
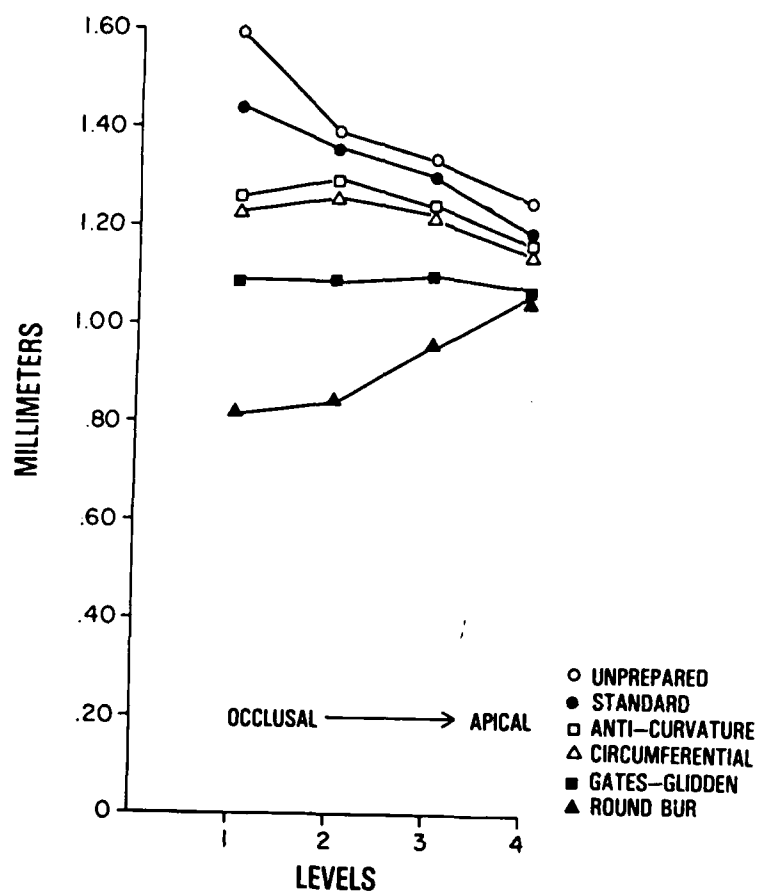
Figure 5.   Diagram of actual number of specimens with less than
            and more than .5mm of dentin remaining in respect to
            the total number of specimens at each level.
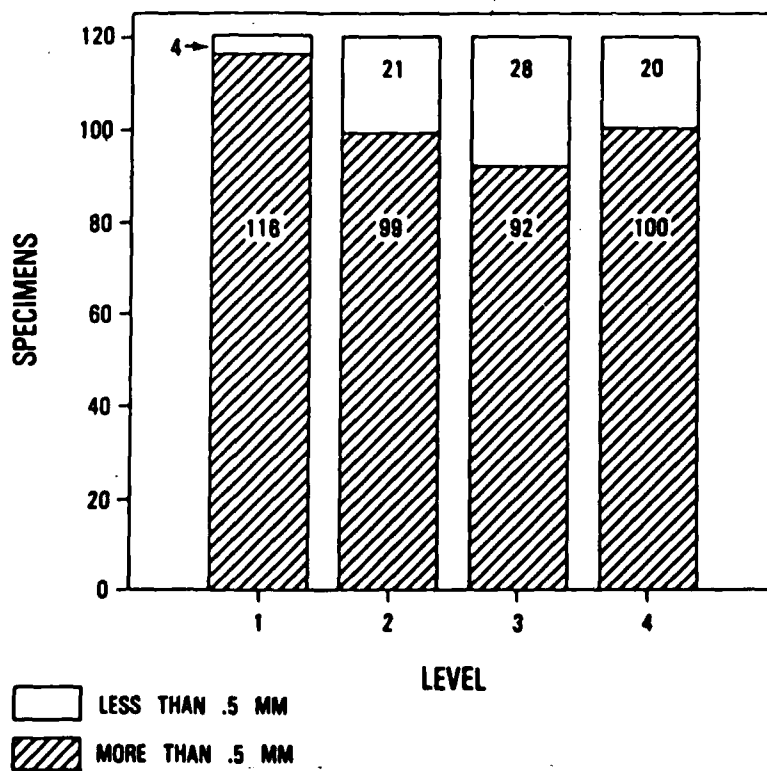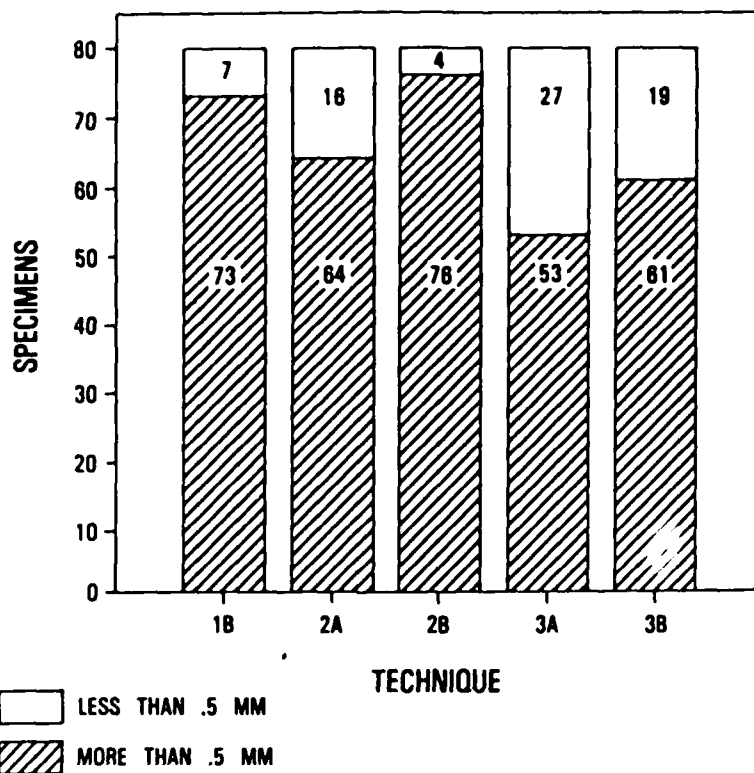
Figure 6.   Mean measurements for each technique of thicknesses of
            mesial walls of the mesial roots.

Figure 7.   Mean measurements for each technique of diameters of the
            canals next to the thinnest wall sections.

MILLIMETERS

OCCLUSAL ⟶ APICAL

■ GATES-GLIDDEN
▲ ROUND BUR
△ CIRCUMFERENTIAL
□ ANTI-CURVATURE
● STANDARD
○ UNPREPARED

LEVELS

MILLIMETERS

1.60
1.40
1.20
1.00
.80
.60
.40
.20
0

OCCLUSAL ──────→ APICAL

○ UNPREPARED
● STANDARD
□ ANTI–CURVATURE
△ CIRCUMFERENTIAL
■ GATES–GLIDDEN
▲ ROUND BUR

1   2   3   4

LEVELS

SPECIMENS

80
70
60
50
40
30
20
10
0

7
73
16
64
4
76
27
53
19
61

1B 2A 2B 3A 3B

TECHNIQUE

☐ LESS THAN .5 MM

▨ MORE THAN .5 MM

SPECIMENS

120
100
80
60
40
20
0

4→
116
21
99
28
92
20
100

1 2 3 4

LEVEL

☐ LESS THAN .5 MM

▨ MORE THAN .5 MM

MILLIMETERS

140
120
100
80
60
40
20

UNPREPARED
STANDARD
ANTI-CURVATURE
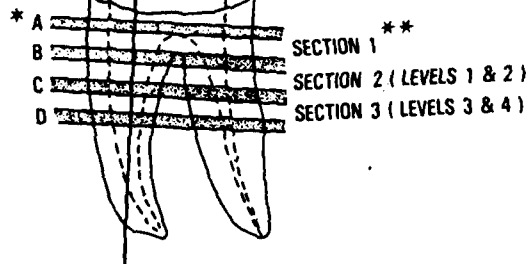CIRCUMFERENTIAL
ROUND BUR
GATES-GLIDDEN

X CLUSA   APICAL

LEVELS

LONG AXIS
MESIAL ROOT

OUTLINE PREPARED
CHAMBER AND CANAL

* A

**

SECTION 1

B

SECTION 2 (LEVELS 1 & 2)

C

D

SECTION 3 (LEVELS 3 & 4)

DAT
ILM